AN OVERVIEW OF TYPES, APPLICATIONS, DESIGN AND FABRICATION OF TENSION LEG PLATFORMS

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ABSTRACT

Tension leg platforms, or TLPs for short, are fixed platforms designed to withstand the environmental and operational loads applied to them in deep water. The name of the tension leg comes from their tendons which are secured on the seafloor by piles and run up to the platform itself. The buoyancy of the platform creates tension in the legs and secures them. In this paper, the different types, applications, design and various fabrication phases are discussed. The aim of this paper is to presents an overview of the tension leg platforms.

Keywords: Applications, Design, Offshore Structure, Oil and Gas, Tension Leg Platform

INTRODUCTION

Tension Leg Platforms are compliant structures held in place by their tension legs (tendons), the tendons are secured in place with piles driven to the seafloor and connected to the platform itself. The platform is buoyant and held in place by a mooring system. The buoyancy of the platform creates tension which secures the legs and limits the movement of the structure. The tendons allow for horizontal movement of up to 6 metres (20 feet), with little vertical movement. TLPs are intended as deepwater platforms. They can operate as deep as 2,000 metres (7,000 feet). ConocoPhillips' Hutton, which was built in the North Sea in 1984, was the first TLP to be constructed. The deepest TLP in the world to date is Big Foot created by Chevron, moored in the Gulf of Mexico over 4,500 meters (1,500 feet) deep. Big Foot was fully operational in 2014.

DIFFERENT TYPES OF TLPS

TLP prototypes have evolved due to fabrication criteria since their introduction in the mid-1980s – more modern versions also include the E-TLP, which has a ring pontoon linking the four air-filled columns; The Moses TLP, which centralizes the four-column hull; and the SeaStar TLP, which contains just one centralized hull column — the SeaStar TLP is a commonly used floating manufacturing facility because TLPs are suitable for a broad variety of water depths (Speight, 2014).

Mini TLP

The SeaStar mini-platform combines the simplicity of a spar and the response features of a TLP. It was created to provide production and utility platforms for deepwater operations. It is a relatively low cost and is used in water depths from 180 to 1,300 meters. The SeaStar platform can be used as an independent production platform on fields having smaller reserves or as a utility, satellite, or early production platform for larger deepwater discoveries (Kibbee, 1996).

The accessibility of these small simplified platforms serves to make the development of deepwater more consistent with the risks and economic systems familiar to the shallow operators. A tension leg mooring may provide a small, secure platform which can provide inexpensive real estate to simplify subsea development. This is the basis for designing the first SeaStar.

The relatively small size of the SeaStar and its low cost are significant advantages. Its cost is low enough that fewer proven reserves support it economically. The associated decrease in delineation activities speeds up the schedule and reduces investment. Unlike sizeable deepwater platforms that can only be constructed in a few yards, all of the SeaStar system elements are compact enough to be provided at affordable prices by established Gulf Coast utilities. The compact design and stable tension leg mooring allow the fairly close deployment of the SeaStar platform to other platforms (Kibbee, 1996).

Operators can balance risk and cash flow in shallow water by building reserves incrementally. The deepwater mini-platform SeaStar provides a vessel which facilitates incremental deepwater production. The presence of these small standardized platforms aims to make deepwater production more consistent with the challenges and economies that shallow-water operators are familiar with (Ardakani & Ketabdari, 2007).

APPLICATIONS

Alongside being used to extract oil from their sub-water reserves, Tension Leg Platforms are also extensively used as carriers of offshore wind turbines. TLPs have a high cost-to-benefit ratio, and their deployment in the appropriate oceanic region is achieved part-by-part by installing the different platform components. Unlike the spar type which needs to be assembled offshore, this TLP wind turbine can be assembled and commissioned onshore, thereby avoiding the logistical difficulties of offshore assembly. The floating platform has a similar anchoring mechanism as the conventional TLP, it is held in position by vertical tendons which are anchored either by suction piles, driven piles, or a template foundation (Ma et al., 2019).

TLP concepts that have been developed for supporting offshore wind turbines are mono-column and multi-column concepts.

Mono-column concepts

MIT was one of the first to work on TLP concepts for wind turbines (Withee, 2004) performed coupled dynamic analysis with a mono-column TLP wind turbine, that had four reinforced pontoons with a square cross-section. The majority of the buoyancy came from the column. The structure also made use of truss structures between the column and the pontoons to increase the stiffness of the system. (Lee, 1998) presented a three-legged TLP concept intended to support a 1.5-MW turbine. Lee modelled the entire structure as a rigid body (Svendsen, 2016).

Multi-column concepts

Adding more columns could improve the hydrostatic properties of the structure, which is beneficial for stability during float-out. However, it also gives rise to increased fabrication complexity. (Suzuki et al., 2011) Developed a TLP for a 2.4-MW turbine. The structure was developed to be situated off the Japanese coast at a water depth of 100 m. The TLP had a centre column, three spokes and three corner columns. The analysis included finding the first ten vibration modes, dynamic response in waves and time domain response to seismic loads (Svendsen, 2016).

TENSION LEG PLATFORM IN COMPARISON WITH OTHER PLATFORMS

Tension Leg Platform technology has many of the operational advantages of a fixed platform and at the same time reduces the cost of production in waterdepths up to about 1,500 metres (4,900 feet). Their production and maintenance operations are similar to those of fixed platforms. However, they are weight-sensitive and may be limited to accommodating heavy payloads (Chakrabarti et al., 2005).

They are among the most widely used type of oil platform, the design of this oil platform is gaining tremendous credibility largely due to its structural singularity and secondly due to its high-efficiency levels in considerably deeper high seas areas of operations.

These steel structures enable stability to be provided on a more permanent basis to the entire oil drilling platform compared with other existing offshore platforms.

TLP characteristics and qualities

The TLP’s structural model avoids disturbances to the drilling operations occurring from the structure's foundation becoming unstable. Thus, although the tension leg platform is prone to minor sideways movement on its surface owing to the tidal motions, the continuity of the drilling activities is well-accounted for because of the structure's stability at its constructional foundation.

For areas subject to regular instability in ocean waters, these kinds in oil platforms are highly suited. Examples of some of the high seas which currently operate TLP platforms include the Gulf of Mexico and certain areas of the North Sea.

TLP advantages and disadvantages

Advantages of TLPs:

i. They are movable and could be used again,

ii. The structure has restricted vertical motion and is secure,

iii. The depth of water does not influence the cost of the TLP, unlike other platforms

iv. In deep waters, the TLP can be conveniently installed

v. Maintenance costs as opposed to other platforms are relatively low.

Disadvantages of the TLPs are:

i. The initial expenditure sum is large,

ii. High cost of subsea,

iii. Occurrence of fatigue problems,

iv. Subsea systems are difficult to maintain, and the storage capacity is comparatively low

DESIGN

A TLP's basic configuration consists of four air-filled columns forming a square, protected and attached by pontoons, similarly to a semisubmersible production platform design. The buoyant hull embraces the platform's topside, and the platform is maintained by an intricate mooring system. The platform's hull buoyancy balances the platform’s weight, which includes clusters of strong tendons to bind the frame to the seabed floor. Piles are driven into the seabed then keep the foundation stationary.

The deck of the platform is located atop the TLP’s hull. A TLP's topside is the same as a standard production platform, consisting of a deck containing the drilling and production equipment, as well as the power module and living quarters. Dry tree wells are popular on TLPs due to the platforms' lessened vertical movement. Most wells producing to TLPs are developed through rigid risers that lift the hydrocarbons from the seafloor to the dry trees on the TLP deck. Steel catenary risers are also frequently used to tie in subsea flowlines and to export pipelines.

TLP designers face the challenge of keeping the natural periods in heave and pitch below the range of substantial wave energy. Increasing the pipe wall thickness of the tendons will control heave period. By placing the tendons on a wide spacing to increase stiffness, the pitch period may be reduced.

In 2003, ExxonMobil launched the Extended Leg TLP, or ETLP, on its Kizomba A field. Its design has four columns that are closer spaced than usual, with ring pontoons and pontoon extensions cantilevered to hold the tendons on a large moment arm (Chakrabarti, 2005).

Design phases

It requires an understanding of the entire design order and its relationship to external constraints such as financial resources, planning, materials and workforce.

It is important to implement the contracting strategy of the operator for architecture, fabrication and installation while preparing the design process. The different parties involved depending on how the contracting is structured between them. The design phase would include planning and scheduling for possible platform concept testing (Kabir Sadeghi & Tozan, 2018).

Some of the key factors that need to be considered when developing TLP plans are as follows:

i. Drilling, machining, quarters,
ii. Environmental, sea and regulatory, Capital and running costs, risk,
iii. Service life,
iv. Contract strategies,
v. Construction Materials, techniques, installation, and assembly.

Conceptual design

Conceptual design transforms the functional requirements during the original design measurements into the offshore nature of the architectural and technological elements.

It includes technological feasibility studies to define such basic elements as length, distance, size, draft, hull form, anchoring mechanism, and well and riser systems that satisfy environmental standards, practical specifications, and viability of installation. The conceptual design includes estimates of the initial lightship weight and anchoring pretension.

The vertical stiffness of the tendon system is typically chosen such that the TLP's heating, rolling and pitching phases have short natural intervals compared to the dominant wave energy periods, to reduce wave amplification (Wilson, J.F.et al, 2003)

Loads used for TLP design

Dead loads are non-variable static weight loads of the TLPs. During structure lifetime, certain sections of the platform framework and any permanent equipment do not alter. Live loads are variable static loads which can be adjusted, moved or eliminated over the lifespan of the structure. Designers should consider maximum and minimum payloads (Bai & Jin, 2016)

Wind Forces

The wind conditions used in a design should be calculated using an appropriate method from wind data obtained accordance with section 5 and would be compatible with certain environmental conditions believed to exist simultaneously, in terms of the joint probability of occurrences. In the surge, sway, and yaw, a TLP has long natural periods which may be stimulated by the energy in the wind spectrum. The influence of the full wind spectrum, including sustained and fluctuating winds will be recognized in evaluating the loads and responses of the wind-induced platform. Such analyzes demand awareness on the speed, spectra, and spatial coherence of wind turbulence. In space and time, wind speed and direction change. Statistical wind properties were measured over durations on the order of an hour shift with height, on length scales characteristic of very large offshore systems. There will be shorter durations with higher average velocities within long durations. A reference value is the mean speed of one hour at a reference elevation of 10 m (GL., 2018).

Wave Impact Forces

Wave slap and wave slamming forces should be measured for local impact on systemic or flotation components and used in the overall solution of motion equation if necessary. The wave slap forces on the columns are a possible cause of "ringing" tendon responses and should be tested for column structure design. Wave-slamming forces attributed to wave-particle velocity and wave run-up jets should be regarded for areas prone to free surface encounter (possibly including top of the column) for hull external appurtenance design.

Earthquakes

Suitable ground acceleration period histories should be acquired for TLP locations where earthquakes are an issue. The vertical ground motion is much more important for the TLP tendon stress responses than horizontal ground motion. Both vertical and horizontal movement can be essential for fundamentals. In API 2A-WSD specific instructions for earthquake ground movement are given (Chandrasekaran, 2015).

Accidental Loads

In designing the structure, the potential for accidental loads arising from various types of collision, dropped or swung objects, or other events should be considered. Applying active and passive measures to resist or absorb such loads should be considered in the design. Such steps may involve, though not limited to, the thickening of the deck plate in places where material handling is undertaken, the protection of risers in the wave zone, or the assessment of the structure and/or anchoring system's energy absorption potential. Such absorption capacity should be consistent with the size and actual speed of vessels working close to the platform, for the latter consideration(Kabir Sadeghi & Tozan, 2018)

FABRICATION AND INSTALLATION

The platform manufacturing method should be considered as part of the preliminary design since the choice of method will have a significant impact on not only the structural design but also on the fabrication feasibility at a selected site (El-Reedy, 2017).

There are four standard platform fabrication methods, and they are as follows:

1) Deck float over:

With this method, the deck is assembled separately from the hull in one piece, floated over the hull, lowered, and mated to it using coordinated ballast and jacking techniques. Deck outfitting is usually done before deck mating.

2) Modules:

The deck facilities are installed with this method in the form of stacked modules atop the hull. This is generally performed prior to the final tow to the installation site at a final outfitting facility. Modules can be built to hold global loading on sliding supports between columns or to "float." In the latter case the global loading between columns should be carried by a structural frame connecting the columns.

3) Integral deck and hull:

The deck is constructed integrally with the hull, following this approach. For this type of fabrication a sufficiently deep dry dock or convenient, sheltered deepwater site is a prerequisite. Deck outfitting may be completed with the fabrication of deck subassemblies or may take place after the fabrication of deck and hull.

4) Deck lifting:

The deck is built in one piece, and is moved offshore and integrated.

TRANSPORTATION

Considering the structural configuration, the architecture and transportation of the LTPs should be designed such that loadings are clearly specified during load-out, tow, and launch. Consideration should be given to applicable regulations and/or codes, such as those of the United States Coast Guard and the International Maritime Organization. Form validation should be used to validate the findings of an experiment. Transactions. Considering the structural design, transportation of the LTPs should be planned so that loadings are clearly defined during load-out, tow, and launch. Consideration should be given to applicable regulations and/or codes, such as those of the United States Coast Guard and the International Maritime Organization. Design testing should be done to validate the results of the analysis. The approaches used would be focused on well-established concepts, procedures, processes, and tools. For such activities, trained skilled staff will be used.

Precautions would be taken to prevent harm to the system during shipment to shore. Transportation on a mobile heavy-lift vessel can be either through towing or carriage. Tugboats will be accompanied to provide defense against harm. For transport, stability requirements should be chosen as suitable for the period, length and position of the route as well as the degree of harm prevention and control offered. The capacity to outrun or look for a safe harbor during a hurricane would have a major effect on the transportation motion criteria. Different transport specifications may depend on whether the vessel is running or not (Gerwick, 2007).

WAVE ANALYSIS AND FURTHER INFORMATION

For additional insight on ecological knowledge along with relevant equations and the details required to describe and analyze these systems, as well as the damage assessment, guidelines, information and suggestions offered by (API, 2010)(Sadeghi, 1989, 1998a, 1998b, 2004, 2007, 2008, 2013), (US Army Coastal Engineering Research Center, 1980, 2002, 2011), (Sadeghi & Nouban, 2010, 2011, 2016, 2017), (Muyiwa & Sadeghi, 2007), (Sadeghi & Aleali, 2008), (Nouban& Sadeghi, 2013, 2014), (Nouban, 2016) and (Nouban et al., 2016, 2017) may be used.

CONCLUSION

The aim of this paper was to give information on Tension Leg platforms and discuss their various applications, different types, and fabrication and design phases. It is important to note that planning is also an important aspect of any offshore platform fabrication. It is important to have a clear plan on production, towing, lifting, transportation, and installation. During fabrication of a platform, it is necessary to execute the operator's contracting strategy. Temporary loads and conditions should also be considered.

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